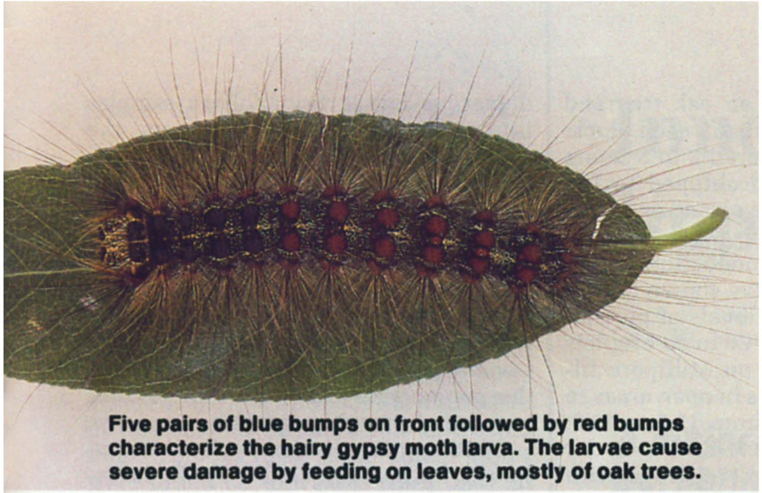
It will take three years to tell if eradication effort has succeeded

Flightless female gypsy moth sits on feltlike egg mass. Darker male with feathery antennae can fly and is attracted over long distances by female sex pheromone.

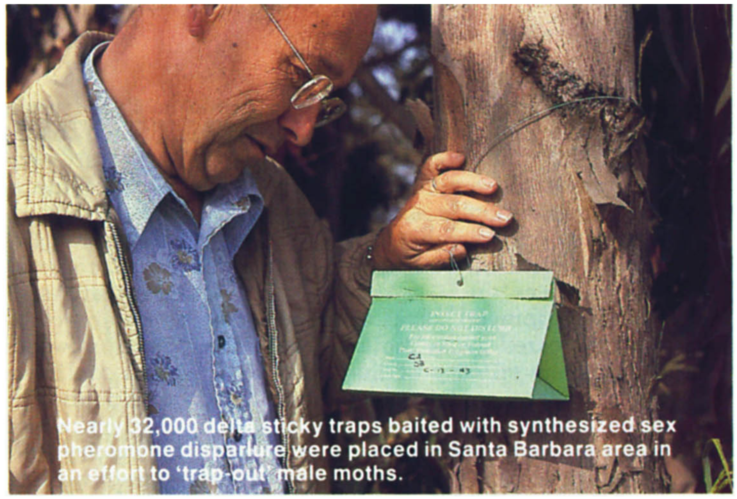
The Santa Barbara gypsy moth eradication effort

Leland R. Brown □ Harry K. Kaya □ Richard C. Reardon □ Robert A. Fusco

Colonies of microbial pesticide *Bacillus thuringiensis* growing on nutrient agar originated with oak leaves pressed on solution. These show that Bt in an oil-emulsion carrier sprayed from a helicopter reached leaves.



Five pairs of blue bumps on front followed by red bumps characterize the hairy gypsy moth larva. The larvae cause severe damage by feeding on leaves, mostly of oak trees.



Nearly 32,000 delta sticky traps baited with synthesized sex pheromone disparlure were placed in Santa Barbara area in an effort to 'trap-out' male moths.

The gypsy moth defoliates oaks and other deciduous trees in forests, parks, and residential areas in the northeastern United States. This insect continues to spread southward and westward, and infestations have been found in British Columbia, Washington, and Oregon. The California Department of Food and Agriculture (CDFA) has captured male moths in traps since 1973. In 1982, CDFA recovered 102 male moths in 14 California counties. In 1983, 171 moths were trapped in 15 counties, but 70 percent of these moths were in only three counties. Gypsy moth egg masses and other life stages are continually being transported on vehicles and outdoor household items to California from infested areas in the East.

The Santa Barbara infestation of gypsy moth, *Lymantria dispar*, was first detected in 1979, when two adult male moths were trapped. Four male moths were trapped in 1980, and 41 in 1981 — a tenfold increase indicating that Santa Barbara probably had one or more breeding populations.

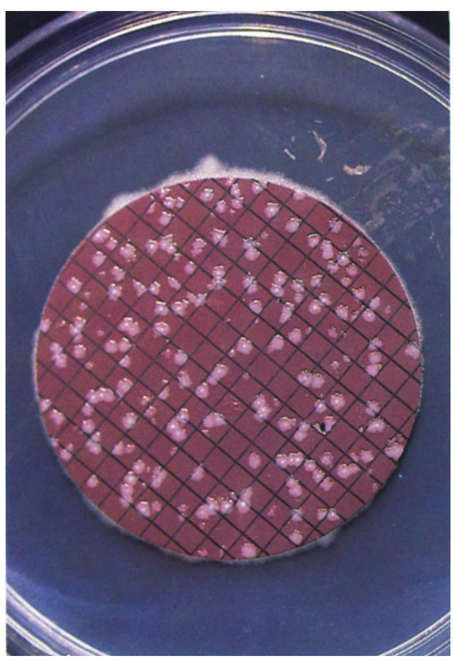
Since most of the trap catches were in the Montecito area of Santa Barbara, 16 square miles were quarantined in late 1981, restricting movement of plant and other materials out of that area. CDFA personnel, in an intensive search, found four gypsy moth egg masses on plants (oak and pyracantha) in two locations. Based on these finds, a decision was made to attempt eradication, using an integrated approach consisting of chemical and microbial pesticides along with mass-trapping of adult males.

Eradication procedure

The four egg masses were enclosed in double-screened cages and monitored daily by CDFA personnel. Egg hatch began in mid-February and continued into the latter part of April. All larvae that emerged were killed within 24 hours after hatching. The hatching of the gypsy moth larvae was used as a basis for the timing and number of applications of chemical and microbial insecticides.

Applications of the chemical insecticide carbaryl (Sevin 80S) by ground sprayer and of the microbial insecticide *Bacillus thuringiensis* (Bt) by air were the initial components of the eradication strategy. Carbaryl was applied to three sites totaling 276 acres, in the Montecito area, selected because egg masses had been found there (two sites) or male moths had been captured in both 1980 and 1981 (one site). All potential host plants of the gypsy moth in a ¼-mile radius around each site were sprayed with carbaryl at the rate of 1.25 pounds of formulation per 100 gallons of water. Three applications were made between March 9 and April 27, 1982, totaling 163,000 gallons of spray.

The entire 16-square-mile quarantined area, including the carbaryl-sprayed areas, was sprayed aerially with Bt so that the known infested area as well as a buffer zone would receive treatment. Bt was chosen because of its low impact on nontarget organisms other than lepidopterous larvae. Dipel 4L, an oil emulsion of Bt, was used. The rate was 12 billion international units at 120 ounces per acre (48 ounces Dipel, 72 ounces water) in each of six applications, by helicopter, on April 2, 6, 13, 20, and 27, and on May 4, 1982. The number of carbaryl and Bt applications was based on the prolonged egg hatch and projected insecticide residual activity.



Millipore filter placed under a tree in spray zone is heavily covered wtih Bt colonies growing from spray droplets.

By early May, the third component of the eradication strategy, delta traps containing the gypsy moth pheromone disparlure, was being deployed on a grid system at 2,000 traps per square mile throughout the entire quarantined area. The purpose was to monitor and trap any adult male gypsy moths that survived the ground and aerial insecticide applications.

Monitoring

We divided the 16-square-mile Bt spray area into 25 blocks for convenience in our monitoring. Foliage from a coast live oak tree, *Quercus agrifolia*, the dominant species in the area, was sampled within each block. Three blocks were established outside the quarantined area as untreated controls. At selected times before and after most Bt applications, approximately 15 terminal branches (12 to 30 cm) from each oak were collected. On most sampling dates, the outer and inner portions of the tree canopy were sampled and stored separately. The samples were air-shipped to the University of California, Davis for laboratory analysis.

Leaf impressions on agar were made to evaluate Bt spray droplet distribution on foliage. A random subsample of 4 to 12 leaves each from the outer and inner canopies was pressed on nutrient agar plates (top and bottom surface of each leaf). After a 24-hour incubation, the plates were examined for Bt colonies.

No Bt was detected on leaf samples taken four days before application. After treatment, all samples from both outer and inner canopies, except those from untreated control oaks, showed Bt endospores present on both upper and lower leaf surfaces.

In a bioassay, sprayed leaves were fed to laboratory-reared gypsy moth larvae to determine the efficacy of the treatment. Petri dishes containing random subsamples of collected leaves (free of insects) from each sample per block were air-shipped to the Pennsylvania Bureau of Forestry, Middletown, Pennsylvania. There, three laboratory-reared third-stage gypsy moth larvae were placed in each petri dish, and mortality was noted on the seventh day.

Considering that the treatments in Santa Barbara were intended to eradicate the gypsy moth, the results were disappointing: most of the larvae fed treated foliage did not die in seven days (see table). No consistent differences in mortality from leaves in the outer and inner canopies were noted.

We used Millipore filters to determine whether or not a particular location received any Bt deposit and to estimate the density of droplets containing viable Bt spores. Immediately before each helicopter application (except the second), one black-gridded Millipore filter was placed under an oak tree and one in a nearby open area in each block. The filters were recovered 3 to 5 hours after the spraying and shipped to UC Davis, where they were placed on nutrient agar plates; colonies were counted after 8 to 12 hours of incubation.

Other researchers have shown that Bt density for acceptable levels of population reduction is about 20 to 30 droplets per square centimeter on Millipore filters. Drops on the filters in open areas in Santa Barbara ranged from 13.7 to 18.8, with an average of 16.7. Filters under the oak trees had 10.5 to 17.7 drops, with an average of 13.7, confirming indications from leaf impressions that the spray was reaching the inner canopy.

The average drop density for all spray applications was higher in blocks closer to the ocean than in those at higher elevations inland. Spraying started at about 6:00 a.m. in blocks closest to the ocean and ended, usually by 3:00 p.m. on the same day, with the inland blocks, nearest the Los Padres National Forest. Greater spray drift may have caused the reduced deposits at higher elevations, both because wind increased during the day, and because the helicopters had to fly higher (200 to 300 feet) above the ridges. Considerable spray drift was observed during all aerial applications.

To evaluate effects of Bt on nontarget organisms, we placed live native lepidopterous larvae from foliage samples into petri dishes and fed them the sprayed foliage. After seven days, dead and moribund larvae were examined microscopically for Bt infection.

In the prespray sampling (March 28), 103 native lepidopterous larvae collected from 22 samples included tortricids (56 percent), geometrids (24 percent), plus gelechiids, noctuids, and dioptids. Generally, after the first two Bt sprays, the percentages collected were similar to those of prespray samples.

Of 88 larvae collected on April 2 (first spray), 49 percent died from Bt infection, including tortricids (41 percent) and geometrids (8 percent). The few gelechiid, noctuid, dioptid, and native lymantriid larvae collected were alive after feeding on Bt-treated foliage for seven days.

After the second Bt spray on April 13, 63 larvae were collected from the Bt-treated and 67 from the untreated blocks. However, the larvae from the treated blocks were from 22 samples and those from the untreated blocks were from 4 samples; that is, larvae in the treated area were over five times as scarce. Fifty-six percent of the larvae from the Bt-treated area died. Mortality due to Bt included tortricids (30 percent), geometrids (5 percent), dioptids (9 percent), noctuids (2 percent), and lymantriids (2 percent).

After the third and subsequent Bt sprays, few larvae were found in either treated or untreated plots, the reduction resulting largely from pupation and natural mortality.

Foliage that had been sprayed with both carbaryl and Bt was collected two to four weeks after the third carbaryl application (one to two weeks after the sixth Bt application). The foliage was shipped to Pennsylvania and bioassayed against third-stage gypsy moth larvae. Also, 10 and 14 weeks following the last insecticide sprays, effects on nontarget organisms were evaluated on two-thirds of the oaks used for sampling.

In our bioassay, in which foliage treated with Bt and carbaryl was fed to gypsy moth larvae, 93 percent mortality was recorded two to three weeks after the third carbaryl application. Even three to four weeks after the third carbaryl application, 68 to 75 percent gypsy moth larval mortality was recorded.

No significant degradation of the carbaryl occurred on trees in the Montecito area 75 days after the last application, according to studies conducted by CDFA personnel. However, we do not know whether it was still active and toxic to gypsy moth larvae after that length of time.

Immediately after the first carbaryl spray on March 29, we counted 114 dead

Mortality, after seven days, of third-stage, laboratory-reared gypsy moth larvae fed oak leaves sprayed with *Bacillus thuringiensis* (Bt) and carbaryl

Leaves collected as related to Bt spray	Treatment	Leaf canopy*	Number of larvae	Mortality
				%
post 3rd	Bt	I	162	16.0
4/13/82	Bt	O	162	11.7
	control	I	9	11.1
	control	O	9	0
pre 4th	Bt	I	54	13.0
4/18/82	Bt	O	54	11.1
	control	I	18	0
	control	O	18	0
post 5th	Bt	I	288	3.8
4/27/82	Bt	O	288	5.5
	control	I	24	0
	control	O	24	0
post 6th	Bt	I	282	32.6
4/27/82	Bt	O	282	37.2
	control	I	24	12.5
	control	O	24	12.5
1 week	Bt	O	108	10.2
post 6th	Bt/carbaryl†	O	72	93.1
5/11/82	control	O	36	5.5
2 weeks	Bt	I	360	8.1
post 6th	Bt	O	360	11.1
5/18/82	Bt/carbaryl‡	I	45	75.6
	Bt/carbaryl‡	O	45	68.8
	control	I	30	10.0
	control	O	30	23.3

* I = inner; O = outer.
† 2 to 3 weeks post 3rd carbaryl spray.
‡ 3 to 4 weeks post 3rd carbaryl spray.

insects on the ground under one tree. These included the following lepidopterous larvae: tortricids (22 percent), geometrids (17 percent), gelechiids (16 percent), noctuids (8 percent), and dioptids (2 percent). The rest were sawfly larvae (15 percent) and dipterous, neuropteran, and hymenopterous insects (7 percent).

Examination of treated trees 10 and 14 weeks after spraying showed some differences in arthropods in untreated, Bt-treated, and carbaryl-plus-Bt-treated trees. For example, more spider mites were found on untreated trees than on Bt- or Bt-carbaryl-treated trees. However, if Sevin sprays caused any depression of beneficial arthropod populations, it was not apparent 10 to 14 weeks after spraying: spiders and lacewings were as numerous on carbaryl-Bt-sprayed trees as they were on trees sprayed with Bt alone and on unsprayed trees.

Mass-trapping with disparlure had no effect on the eradication effort, since no male moths were trapped.

Conclusions

In the laboratory tests to monitor effectiveness of the sprays, it was disappointing to find such low average Bt drop density as well as the low mortality of third-stage gypsy moth larvae fed foliage from areas treated with Bt only. These tests showed higher mortality on foliage that had been sprayed with both carbaryl and Bt.

If the gypsy moth breeding populations in Santa Barbara were, indeed, focused on the restricted locations where carbaryl plus Bt were sprayed, it is reasonable to expect that these sprays were even more effective on very young larvae. Our results do not permit adequate assessment of the relative merits of Bt and carbaryl in eradicating gypsy moth, since no area was treated with carbaryl alone. Treatments did not cause any permanent upsets in the populations of insects normally found in oaks.

Final results of the eradication effort will not be known until the treated area has been sampled over three consecutive years for presence of gypsy moth life stages. During 1983, four male moths were trapped in Santa Barbara, none of which were in the zone sprayed in 1982.

Leland R. Brown is Professor of Entomology, University of California, Riverside; Harry K. Kaya is Associate Nematologist, Department of Nematology, and Associate Professor, Department of Entomology, UC Davis; Richard C. Reardon is Research Entomologist, U.S. Forest Service, formerly at Davis; and Robert A. Fusco is former Supervisor, Biological Control Section, Bureau of Forestry, Middletown, Pennsylvania. *These investigations were supported in part by CDFA Contract No. 3-440377-20866-5.*

Innovative approaches improve farm labor

John W. Mamer □ Robert W. Glover

A major educational effort to improve personnel management practices would benefit both workers and employers

The United States agricultural employment system is largely casual. Most employers and employees have few continuing ties that provide an assured quality work force on the one hand and adequate farmworker livelihood on the other. Labor practices are commonly those of a simpler, less commercial agriculture of an earlier time and are not suited to the needs of today's far more technically and organizationally sophisticated agriculture.

The changes in agriculture have led to some reassessment of traditional farm labor management and market mechanisms. A more mechanized highly technical, and commercial agriculture requires skilled workers. Workers are increasing pressure, and more employers are recognizing the need to reduce instability and improve employment efficiency, and hence the wage, of career farmworkers. Additional impetus for change has been the application to agriculture of employment, safety, health, and other labor standards already in force in other industries.

Nevertheless, low income and only intermittent employment for many farmworkers are still the rule rather than the exception. Each year, too many growers face an uncertain supply of labor while trying to cope with a casual labor market. Even where job-matching mechanisms exist, frequently they do not operate satisfactorily, or growers and workers lack the labor market skills to use them effectively.

Before labor use can be improved, the full dimensions of the problem, as well as recent trends and innovations, must be understood.

This article is based on *Agricultural Labor in the 1980s: A Survey with Recommendations*, a report of the Agricultural Employment Work Group organized by the U.S. Department of Agriculture to study labor issues in agriculture. The group included representatives of agricultural employer and farmworker interests, agricultural labor economists and personnel specialists, and government representatives. The report is available from John Mamer, 319 Giannini Hall, University of California, Berkeley, California 94720.

New approaches

In various places across the United States, labor problems are being approached in ways new to agriculture, ranging from collective bargaining to thorough application of modern labor management principles and practices. Unionization of farmworkers is being pursued with a new vigor in some areas. Although collective bargaining in agriculture goes back many years both in California and in the rest of the country, it is impossible to predict how widespread the unionization movement will become.

Some innovative farm employers have made progress in improving conditions of employment by applying ideas and methods long used by progressive nonagricultural employers. These farm employers include a citrus harvesting cooperative of 270 grower members in the coastal valleys of California, a large diversified agricultural producer in southern Florida, members of the shade tobacco growers' association in Massachusetts and Connecticut, a large association of canners and freezers in Wisconsin, and one of the nation's largest apple growers in Pennsylvania.

Through their personnel policies and practices, these firms have sought to establish a continuing relationship with their employees. They have evolved methods of meeting their skill needs while taking into account their workers' desires and concerns.

The harvesting cooperative, for exam-